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RESEARCH MEMORANDUM

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PRELIMINARY TRANSIENT PERFORMANCE DATA ON THE FUEL CONTROL OF THE XRJ47-W-5 RAM-JET ENGINE

By Henry J. Welna and Ivan D. Smith

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

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RESEARCH MEMORANDUM

PRELIMINARY TRANSIENT PERFORMANCE DATA ON THE FUEL CONTROL OF THE XRJ47-W-5 RAM-JET ENGINE

By Henry J. Welna and Ivan D. Smith

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SUMMARY

A brief program was undertaken to determine the characteristics of the fuel control (Hydrocon) of the 48-inch diameter XRJ47-W-5 ram-jet engine. The control was installed on the engine in a free-jet facility. Data were obtained in the form of oscillograph traces showing the time history of the fuel system pressures, fuel flow, and engine inlet total pressure in response to changes in the control signal pressure. The data presented in this report are for step changes (from ±15 to ±30 percent) in Hydrocon signal pressure at simulated altitudes of 67,000 and 73,000 feet at a flight Mach number of 2.75.

INTRODUCTION

As part of an over-all program to evaluate the altitude performance of the XRJ47-W-5 ram-jet engine in a Mach 2.75 free-jet facility at the NACA Lewis laboratory, the response of the fuel control and engine to step changes in control signal pressure has been investigated. The fuel control (Hydrocon) corrects the fuel flow for changes in altitude, flight Mach number, and angle of attack, according to a predetermined schedule, by sensing a pressure (control signal pressure) on the flight vehicle.

The data were obtained as oscillograph traces which showed the time history of the fuel system pressure, fuel flow, and engine inlet total pressure following a step change in control signal pressure. Data are presented in preliminary form for altitudes of 67,000 and 73,000 feet at a flight Mach number of 2.75.

A check on the accuracy of the calibration factors listed on the oscillograph traces has been made but no analysis of the data is presented.

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APPARATUS

Engine and Installation

A diagram of the free-jet installation of the XRJ47-W-5 ram-jet engine in an altitude chamber of the NACA Lewis laboratory is shown in figure 1. The engine combustor was 48 inches in diameter and in this investigation, the exhaust nozzle throat was 35.9 inches in diameter. A detailed description of the free-jet installation is presented in reference 1.

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Inlet air entered the chamber and passed through smoothing screens before entering the supersonic nozzle. Part of the air from the supersonic nozzle entered the inlet diffuser and ram-jet engine and the rest passed through the jet diffuser into the exhaust system. The hot gases from the engine also passed into the exhaust system.

The fuel control was mounted on the side of the engine. It consisted of an air turbine fuel pump driven by air bled from the engine diffuser and a Hydrocon (fig. 2). The Hydrocon is a bellows actuated needle valve.

Instrumentation

The transient responses of the fuel control variables were recorded on a multiple channel, direct-inking, magnetic motor oscillograph. The location of the measuring stations for the fuel control is shown in figure 2 and the location of the measuring station of the engine-inlet (diffuser-exit) pressure is indicated in figure 1. The station 3 total-pressure tube which gave a reading nearest to the average station 3 total pressure was selected for the oscillograph trace. The sensing devices used for indicating variations of each measured item are described in table I.

PROCEDURE

The engine was operated at altitudes of 67,000 and 73,000 feet, at a flight Mach number of 2.75 and inlet air temperatures from 950 to 1007° R. At each of several fuel-air ratios, both positive and negative step changes were made by introducing a known change (from ±15 to ±30 percent) in the Hydrocon signal pressure and the resultant behavior of the engine and control were observed. The pressure source was a nitrogen-bottle accumulator system.

The change in Hydrocon signal pressure and the resultant changes in station 3 and turbine-inlet total pressures, fuel-pump outlet and fuel-

manifold pressures, and fuel flow were recorded on oscillograph traces. The oscillograph traces were calibrated from steady-state readings taken before and after each step change. The individual calibration factor of each trace was determined, comparable calibration factors were averaged, and the average value is indicated on each trace.

PRESENTATION OF DATA

The test conditions for the oscillograph traces, which are presented in figures 3 to 15, are given in table II. On the traces, the steady-state values are given before each step change. Each trace is identified by a label below which is given the calibration factor for the trace. As indicated by the calibration factors, all traces are considered linear. The arrows on each figure indicate the direction in which the variable is increasing.

The accuracy of the calibration factors is indicated in table III, which gives the average calibration factors and the maximum deviation of an individual calibration factor from the average value. As noted in table III, the maximum error (±50 percent) occurred in the calibration factor for the fuel-pump outlet pressure. This error is reasonable since the pressure level was high (about 300 lb/sq in.) and the changes in fuel pump outlet pressure were small (about 10 lb/sq in.); an absolute error of ±1.0 pound per square inch per millimeter is indicated for the calibration factor.

During the course of this investigation no difficulties were encountered in the operation of the fuel control. The operation of the control was stable at all times.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, January 29, 1954

REFERENCE

1. Seashore, Ferris L., and Hurrell, Herbert G.: Starting and Performance Characteristics of a Large Asymmetric Supersonic Free-Jet Facility. NACA RM E54A19, 1954.

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TABLE I. - INSTRUMENTATION

Measured quantity	Steady-state instrumentation	Transient instrumentation
Turbine-inlet total pressure	Tetrabromoethane manometer	Aneroid-type pressure sensor with strain-gage element
Hydrocon signal pressure	Mercury manometer	Aneroid-type pressure sensor with strain-gage element
Station 3 total pressure	Tetrabromoethane manometer	Aneroid-type pressure sensor with strain-gage element
Fuel-pump outlet pressure	Bourdon-type gage	Aneroid-type pressure sensor with strain-gage element
Fuel-manifold pressure	Bourdon-type gage	Aneroid-type pressure sensor with strain-gage element
Fuel flow	Variable-orifice flow meter	Positive displacement electronic flow meter

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TABLE II. - OSCILLOGRAPH TRACE CONDITIONS

Figure number	Engine air flow, lb/sec	Simulated altitude, ft	Flight Mach number	Engine inlet temperature, °R	Initial fuel-air ratio	Direction of step
3	58.9	73,000	2.75	971	0.0366	Increase
4	58.1	73,000	2.75	999	.0421	Decrease
5	58.5	73,000	2.75	994	.0358	Decrease
6	58.7	73,000	2.75	986	.0306	Increase
7	58.1	73,000	2.75	1002	.0455	Decrease
8	58.0	73,000	2.75	1007	.0426	Increase
9	60.5	73,000	2.75	978	.0406	Decrease
10	61.0	73,000	2.75	981	.0298	Increase
11	80.0	67,000	2.75	955	.0357	Decrease
12	80.3	67,000	2.75	952	.0306	Increase
13	80.2	67,000	2.75	950	.0354	Increase
14	79.9	67,000	2.75	956	.0415	Decrease
15	80.3	67,000	2.75	956	.0406	Decrease

TABLE III. - OSCILLOGRAPH TRACE CALIBRATIONS AND ERRORS

Figure number	Turbine-inlet total pressure, lb/sq ft abs			Hydrocon signal pressure, lb/sq ft abs			Station 3 total pressure, lb/sq ft abs		
	Calibration, (lb/sq ft)/mm	Error in calibration, percent	Error in parameter, (lb/sq ft)/mm	Calibration, (lb/sq ft)/mm	Error in calibration, percent	Error in parameter, (lb/sq ft)/mm	Calibration, (lb/sq ft)/mm	Error in calibration, percent	Error in parameter, (lb/sq ft)/mm
3	13.1	±1.5	±0.2	7.5	±3.5	±0.25	4.2	±10	±0.4
4									
5				21.1	±15	±3.2			
6									
7									
8									
9	7.9	±5.5	±.4						
10									
11	13.1	±1.5	±.2						
12									
13									
14									
15									

Figure number	Fuel-pump outlet pressure, lb/sq in. abs			Fuel-manifold pressure, lb/sq in. abs			Fuel flow, lb/hr		
	Calibration, (lb/sq in.)/mm	Error in calibration, percent	Error in parameter, (lb/sq in.)/mm	Calibration, (lb/sq in.)/mm	Error in calibration, percent	Error in parameter, (lb/sq in.)/mm	Calibration, (lb/hr)/mm	Error in calibration, percent	Error in parameter, (lb/hr)/mm
3	2.1	±50	±1.0	1.3	±12	±0.16	300	±15	±45
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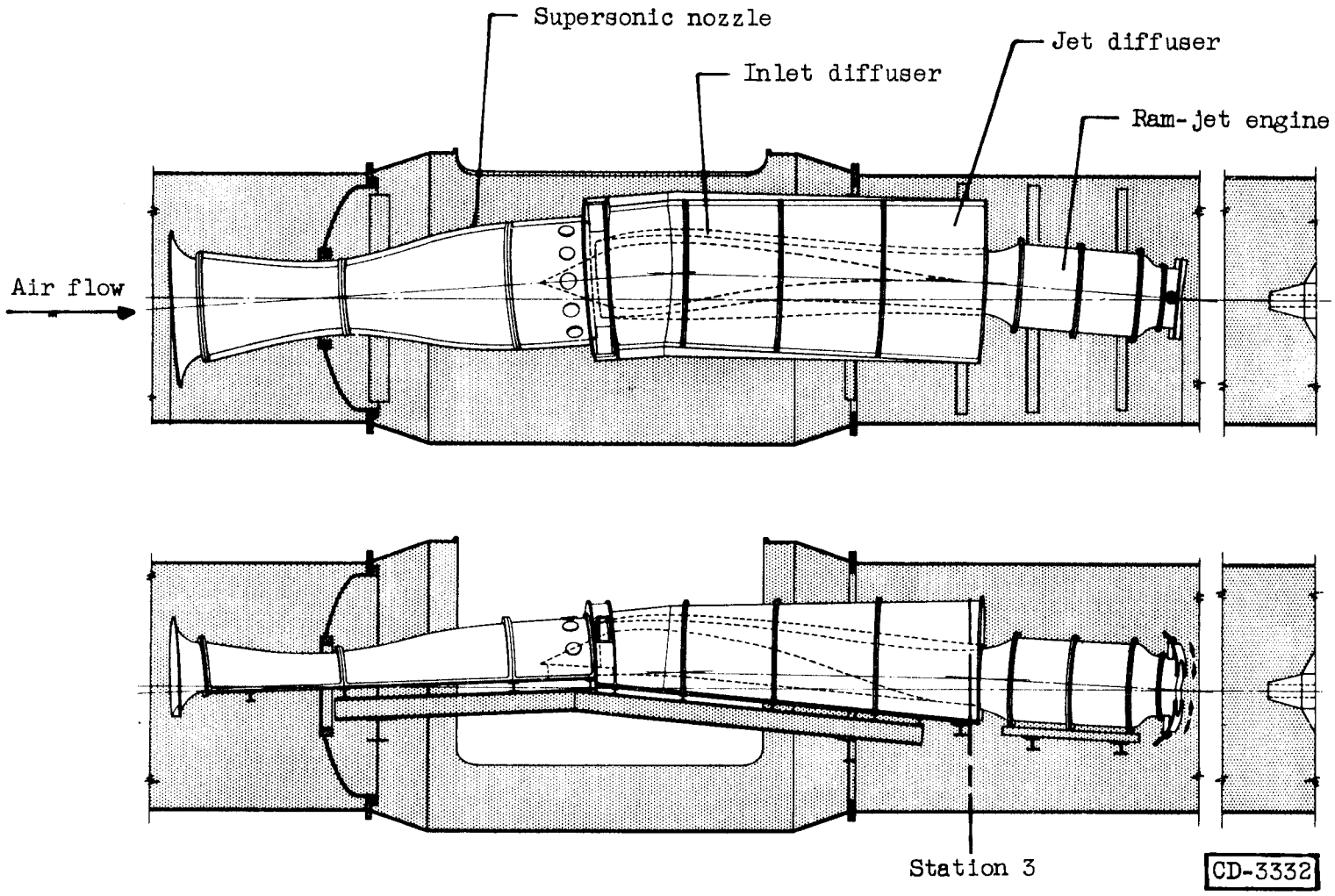

Figure 1. - Schematic diagram of installation of ram-jet engine in altitude chamber.

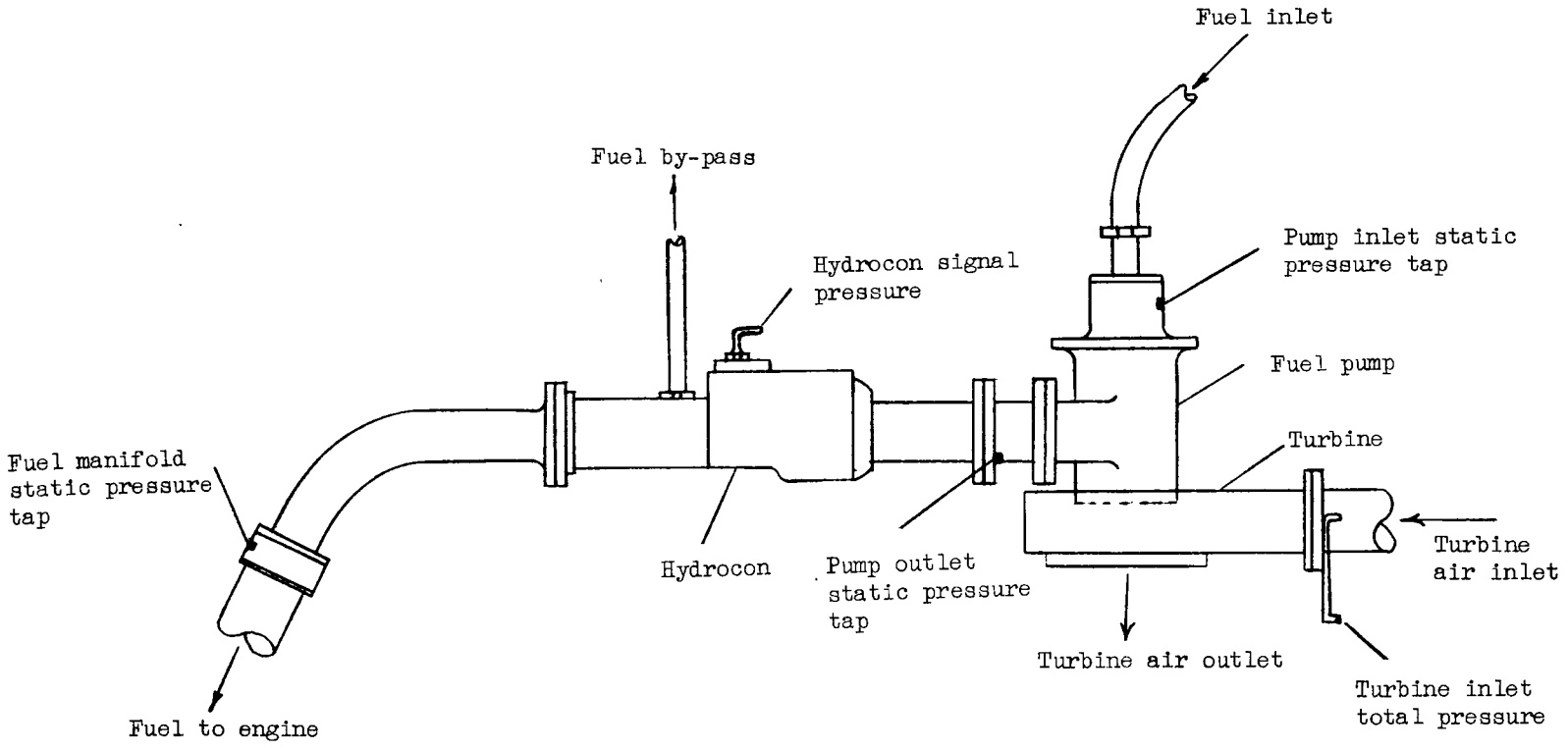

Figure 2. - Schematic diagram of fuel system and instrumentation.

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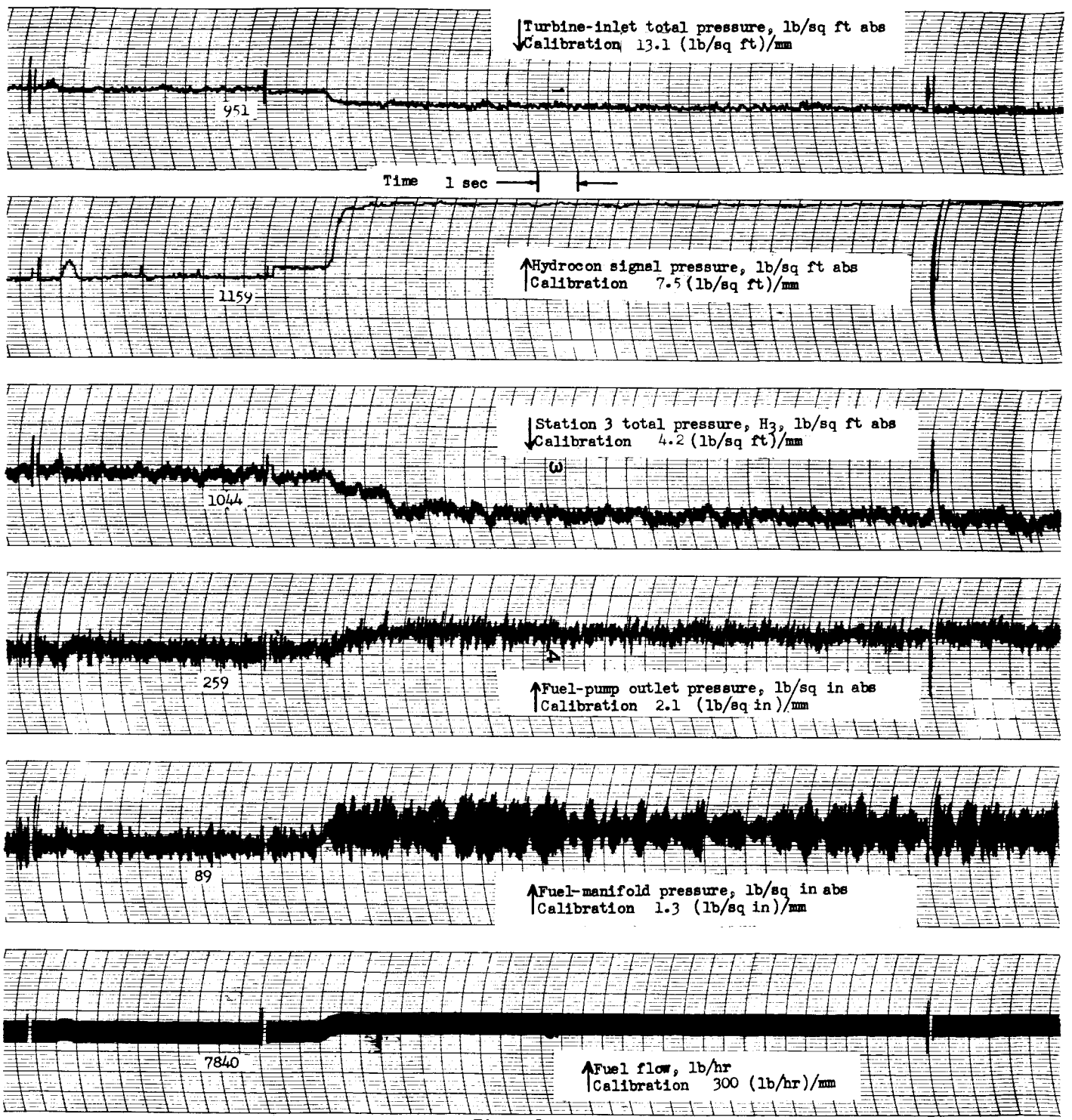

Figure 3

Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 971°R; engine air flow, 58.9 lb/sec.

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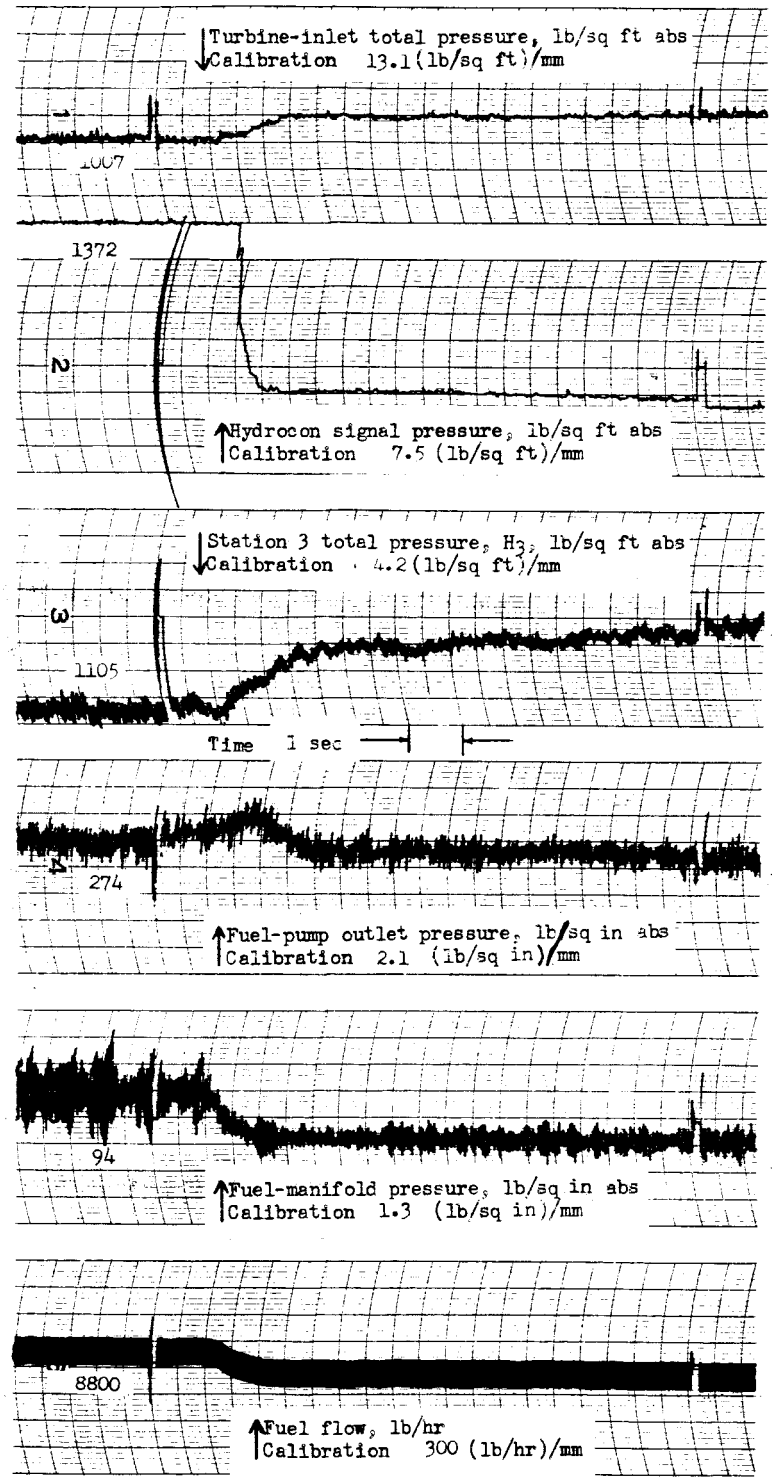

Figure 4

Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 999°R ; engine air flow, 58.1 lb/sec.

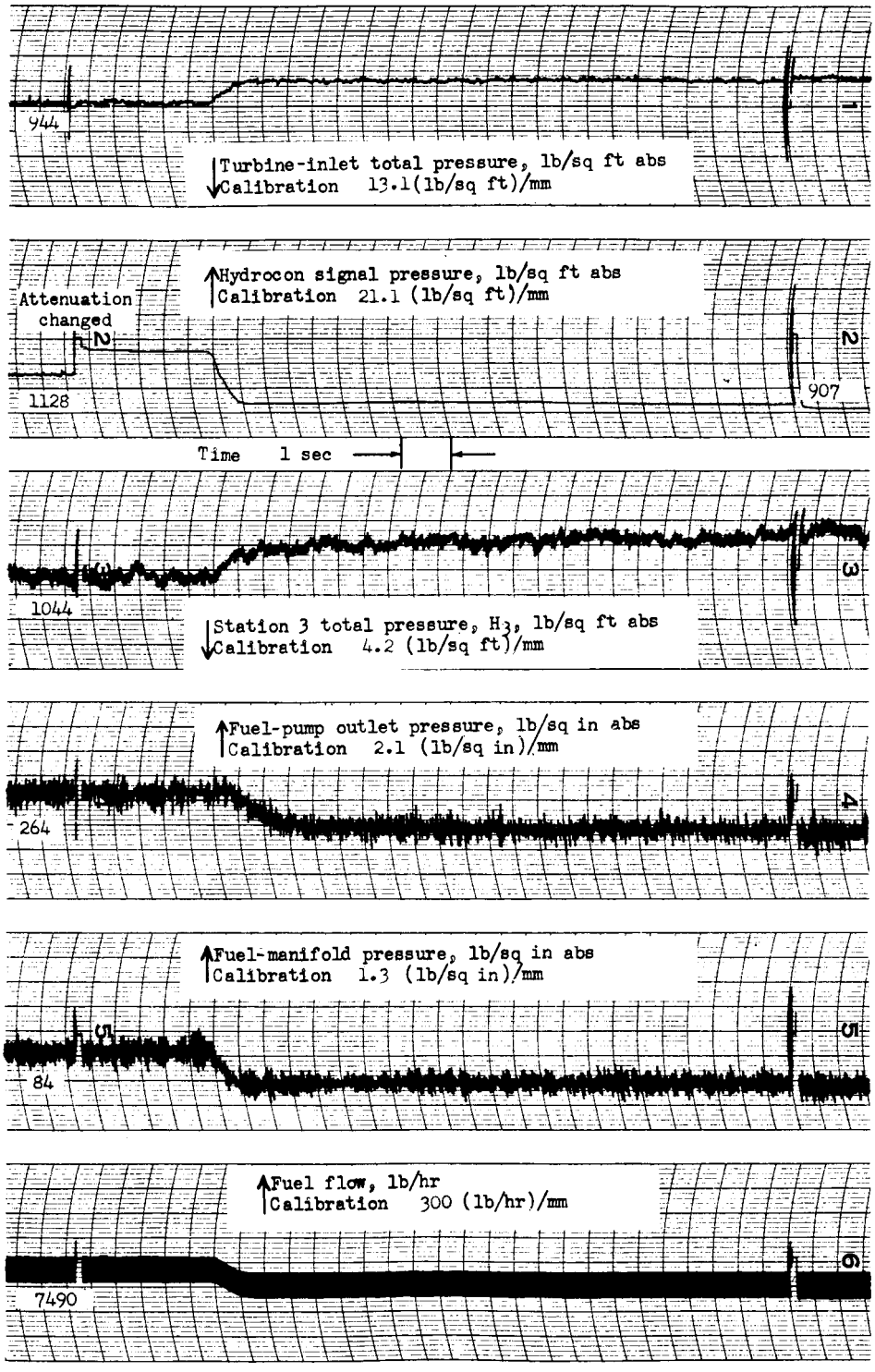

Figure 5

Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 994°R ; engine air flow, 58.5 lb/sec.

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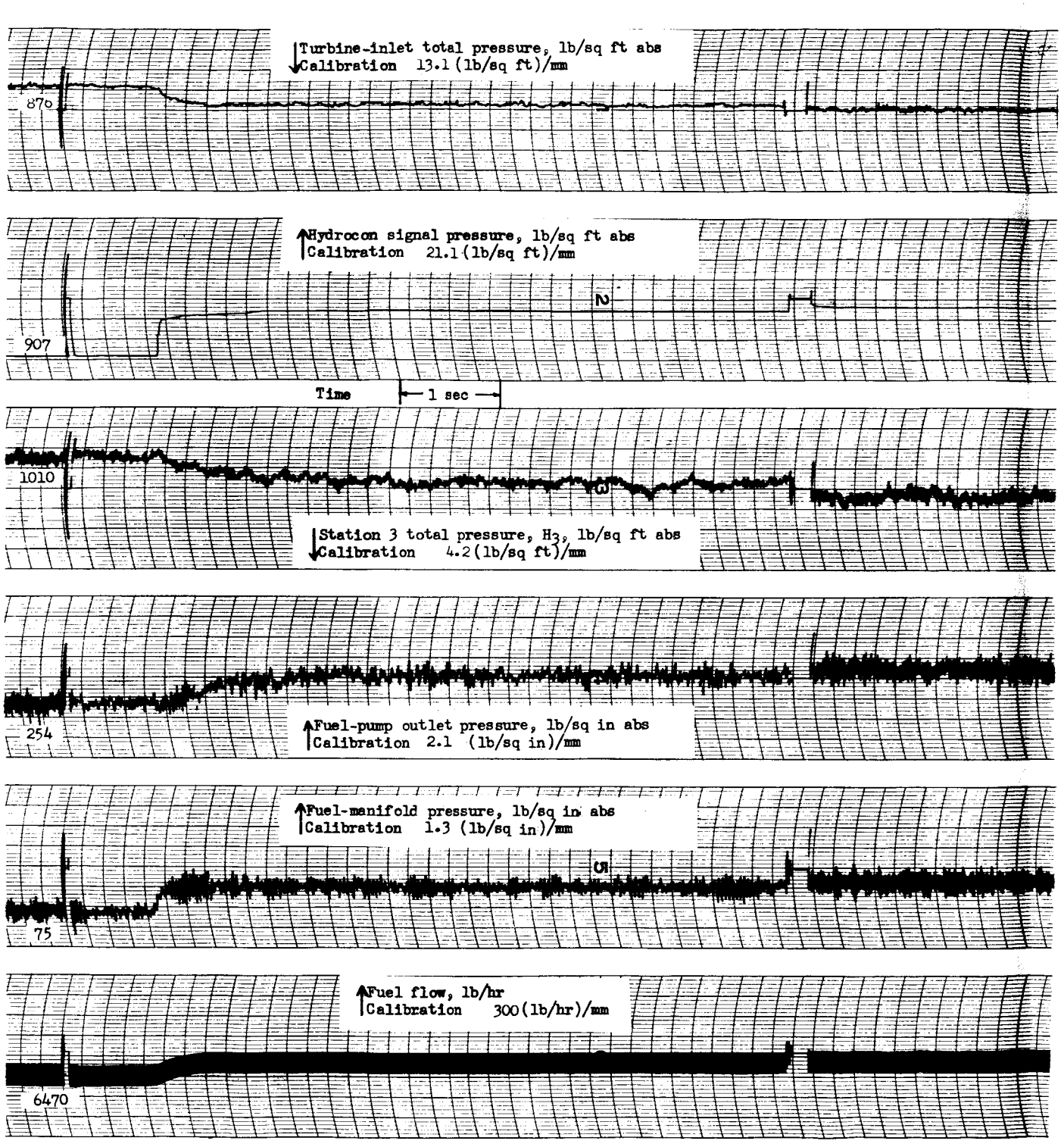

Figure 6
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 986°R ; engine air flow, 58.7 lb/sec.

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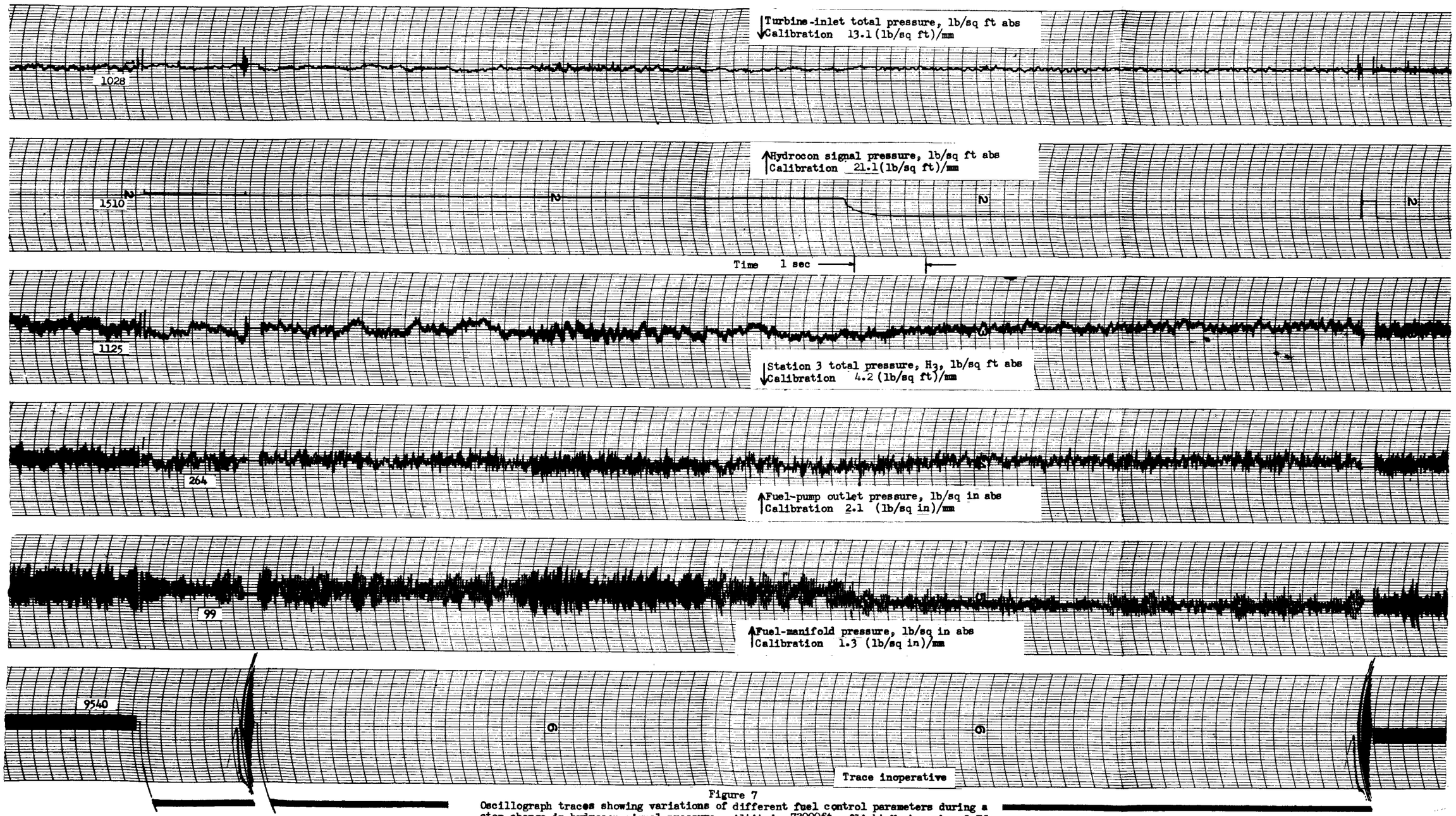

Figure 7
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 1002°R ; engine air flow, 58.1 lb/sec.

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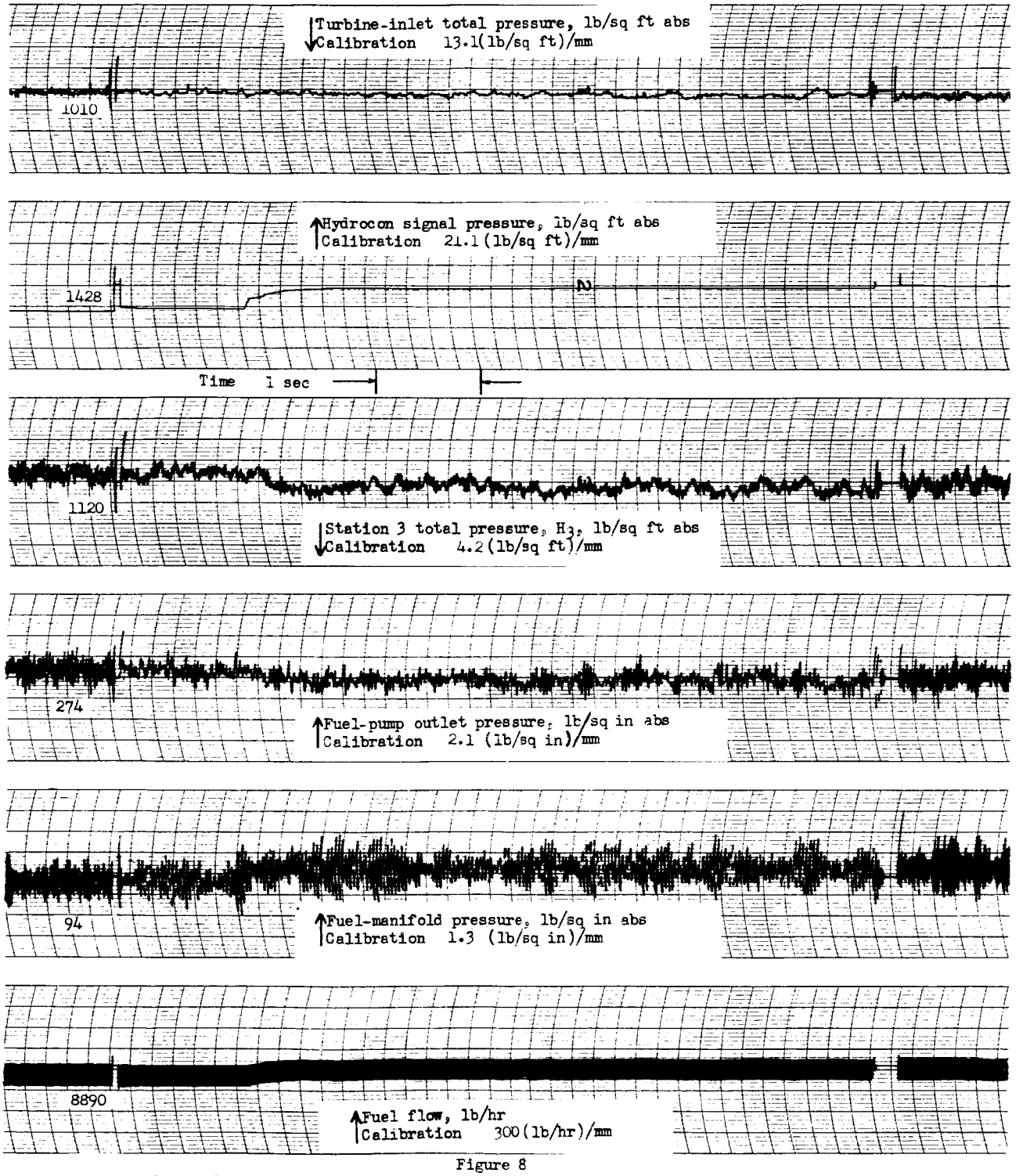

Figure 8

Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 1007°R; engine air flow, 58.0lb/sec.

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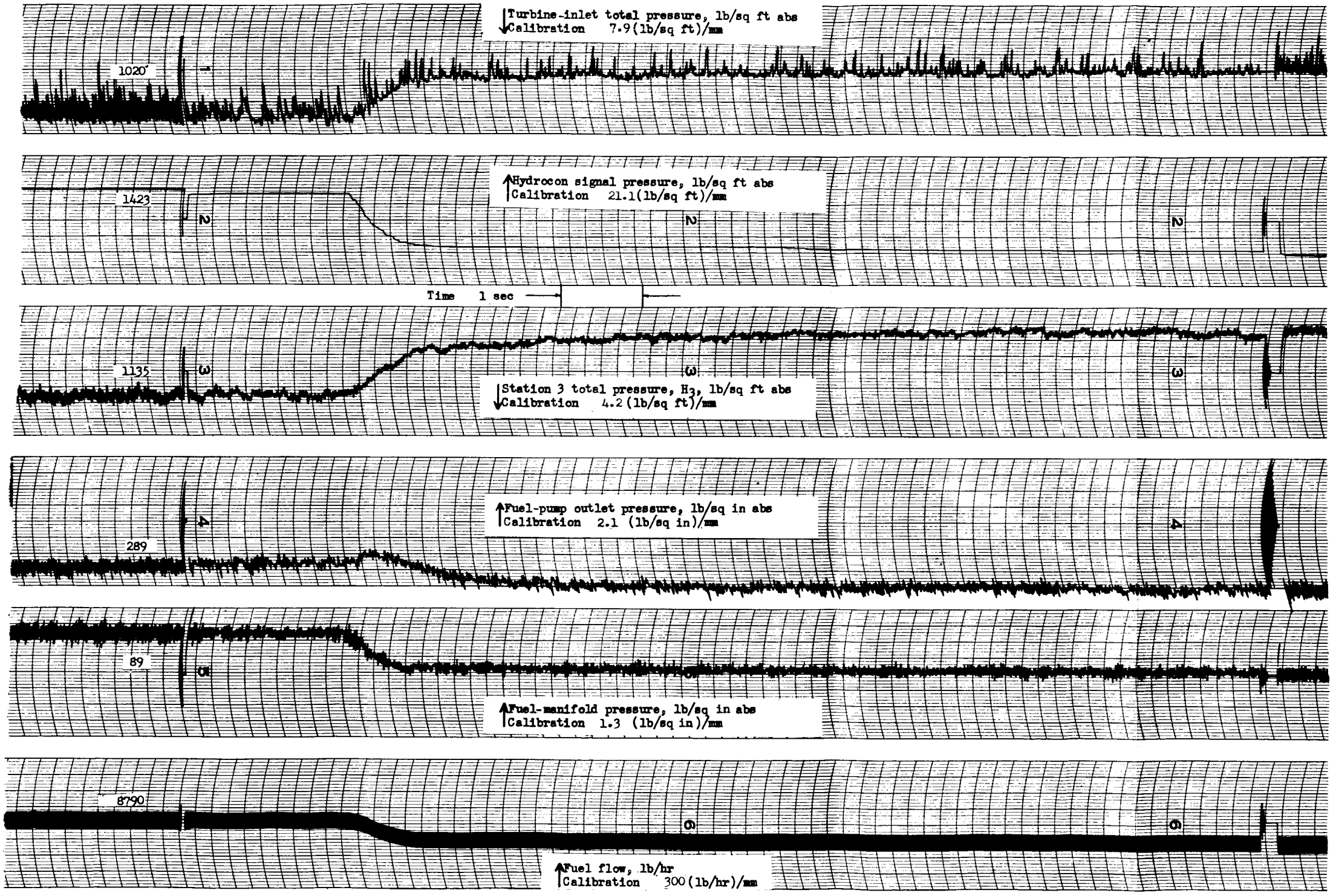

Figure 9
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 978°R ; engine air flow, 60.5 lb/sec.

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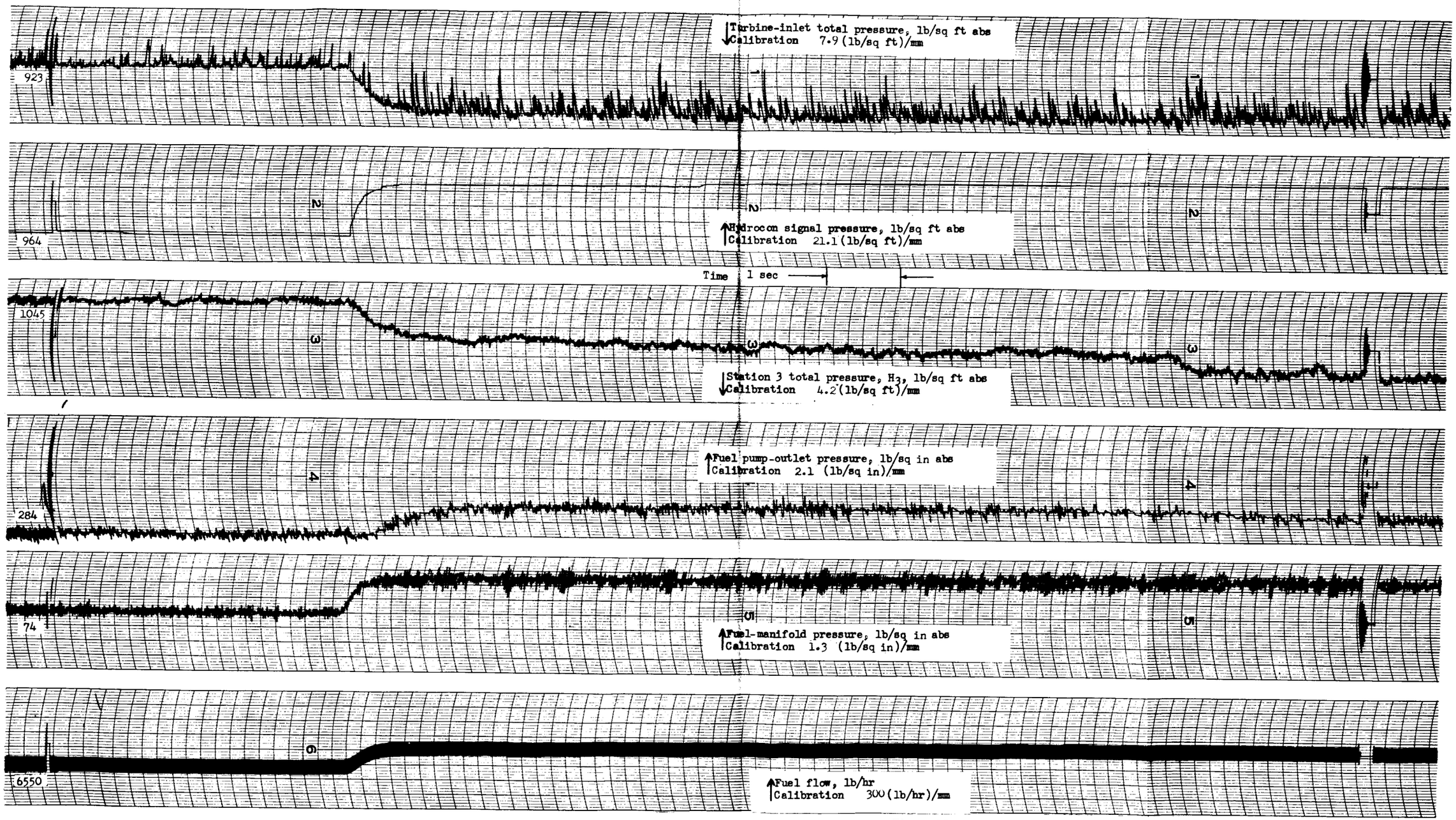

Figure 10
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 73000ft ; flight Mach number 2.75; engine-inlet air temperature, 981°R ; engine air flow, 61.0 lb/sec.

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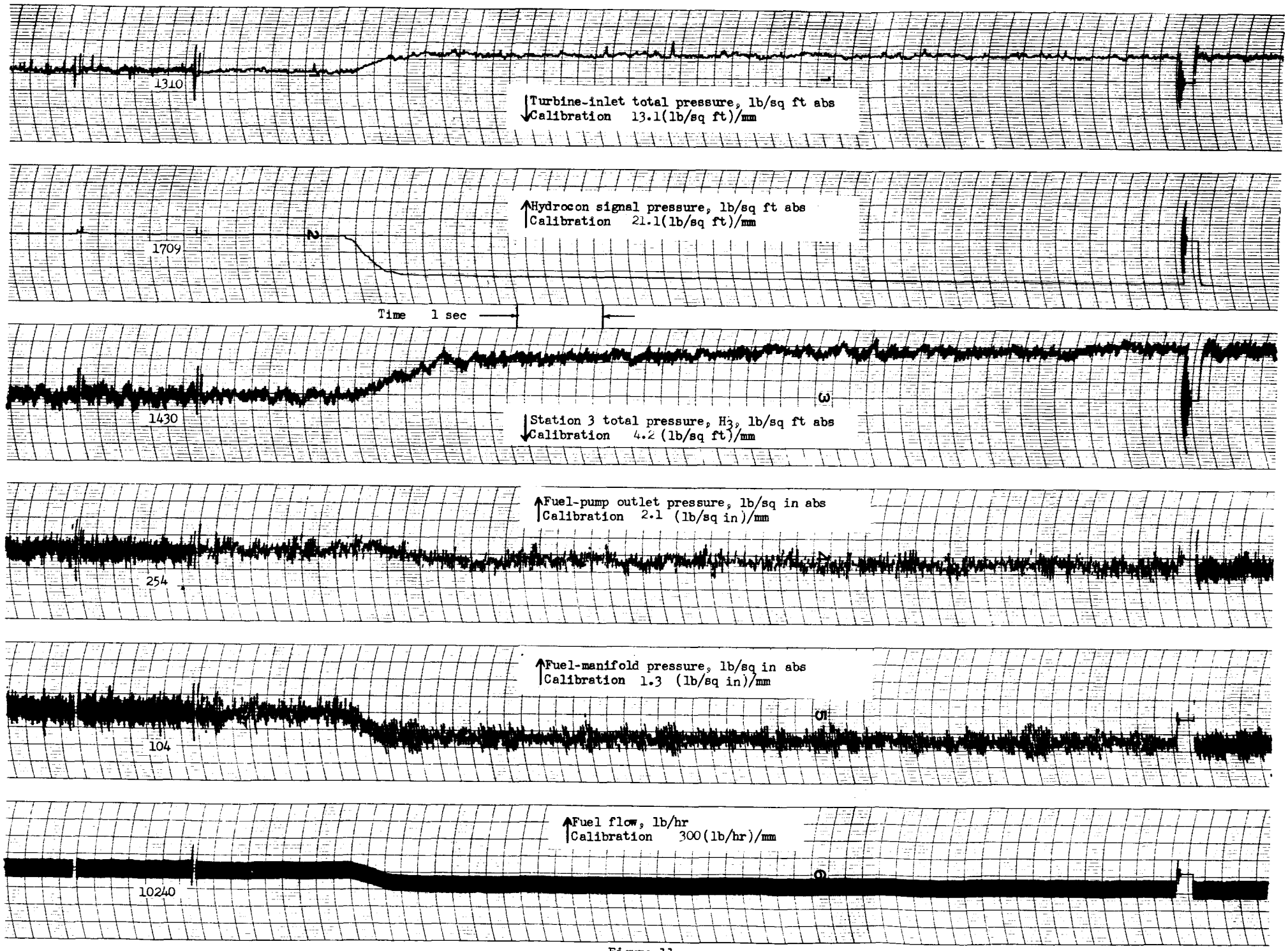

Figure 11
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 67000ft; flight Mach number 2.75; engine-inlet air temperature, 955°R ; engine air flow, 80.0 lb/sec.

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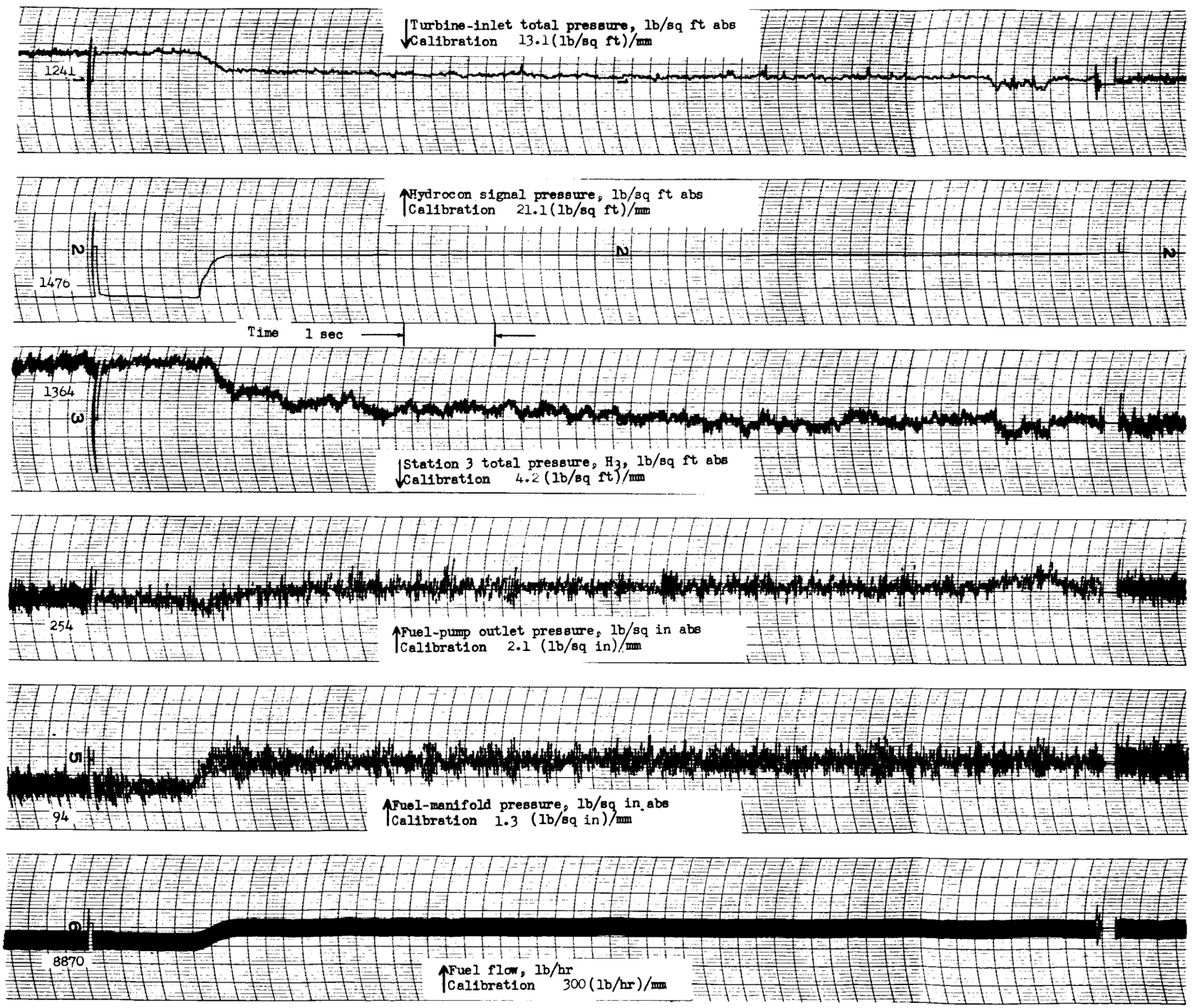

Figure 12

Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 67000ft; flight Mach number 2.75; engine-inlet air temperature, 952°R ; engine air flow, 80.3 lb/sec.

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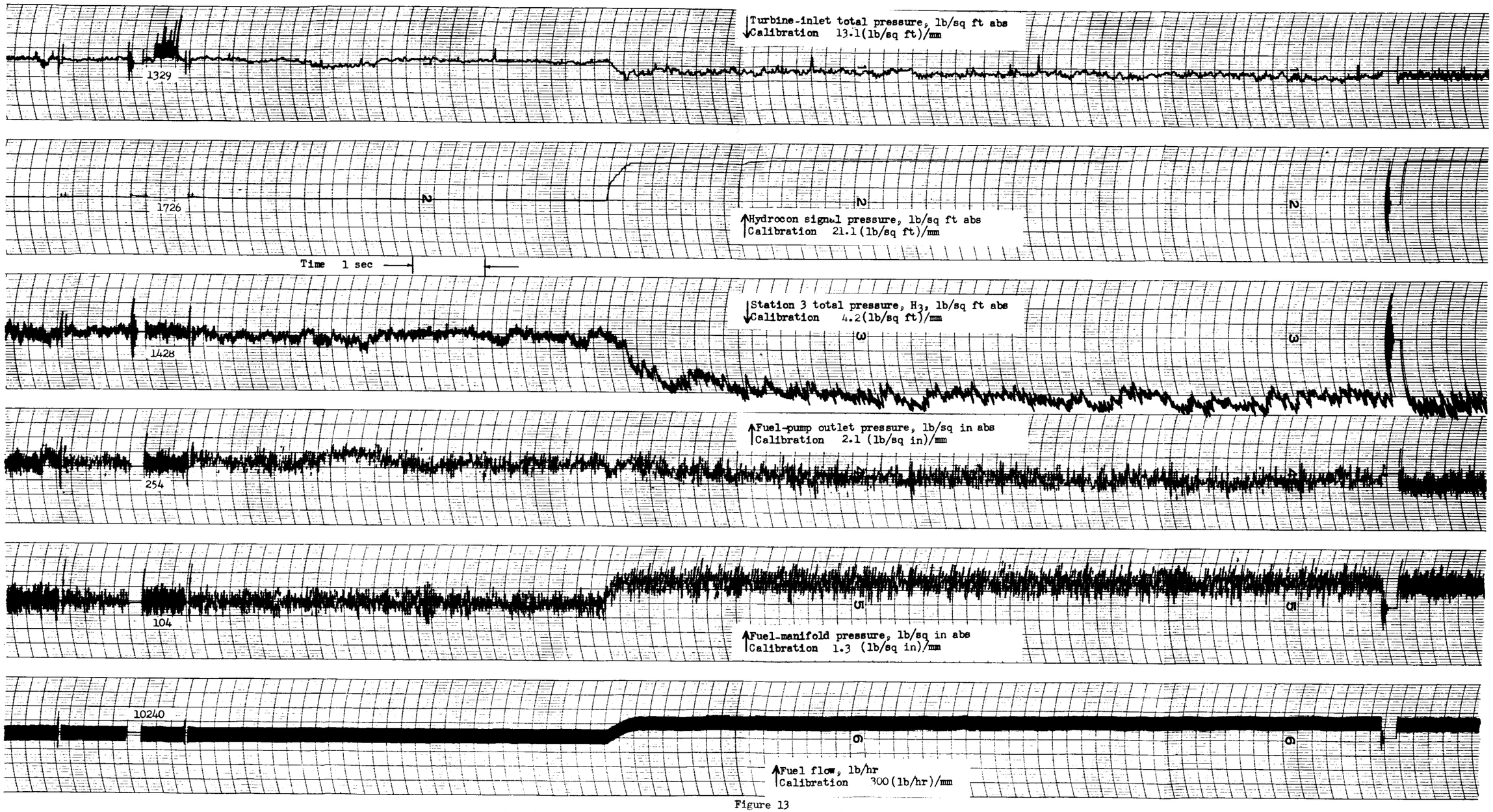

Figure 13
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 67000ft; flight Mach number 2.75; engine-inlet air temperature, 950°R; engine air flow, 80.2 lb/sec.

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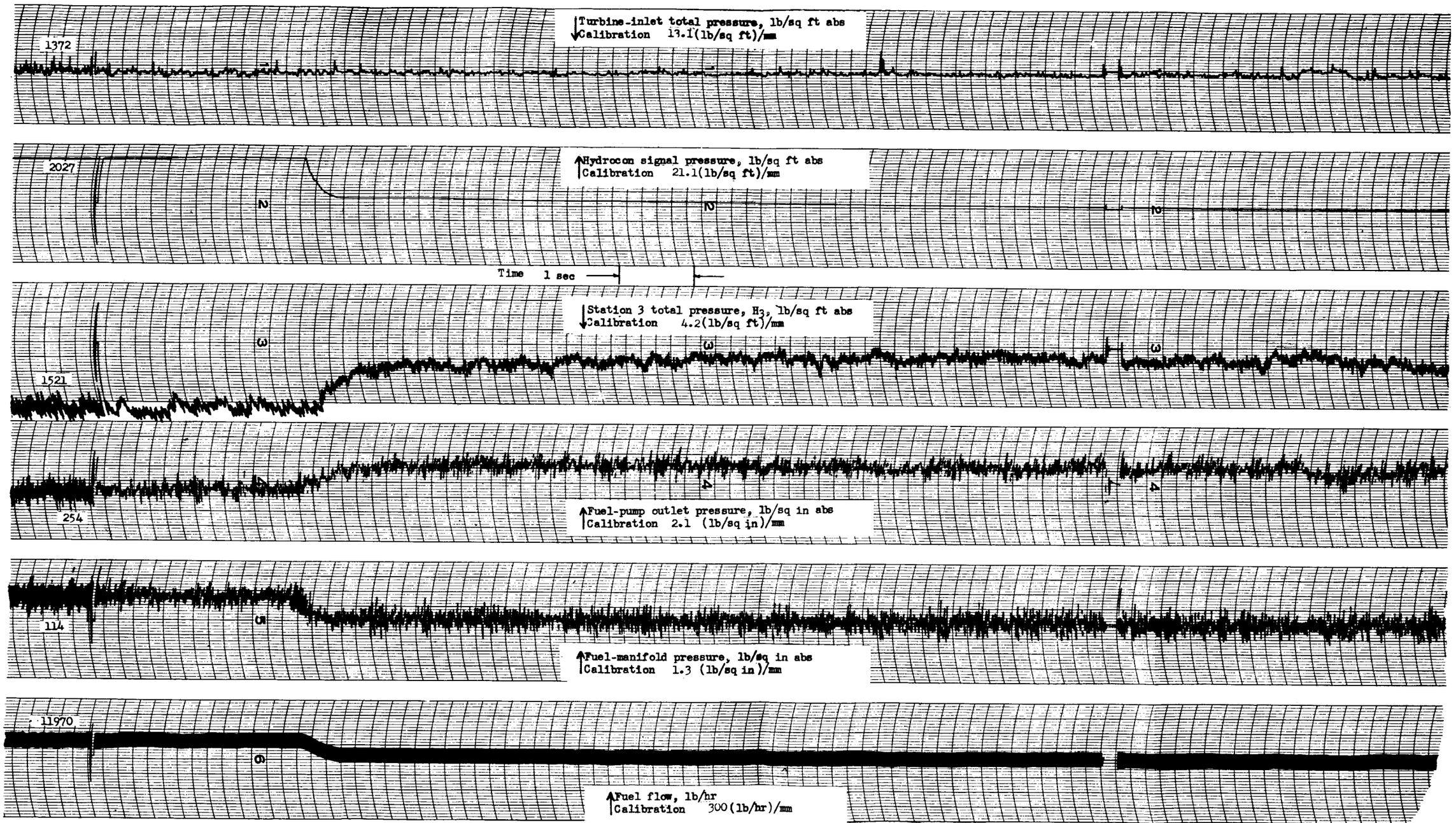

Figure 14
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 67000ft ; flight Mach number 2.75; engine-inlet air temperature, 956°R; engine air flow, 79.9 lb/sec.

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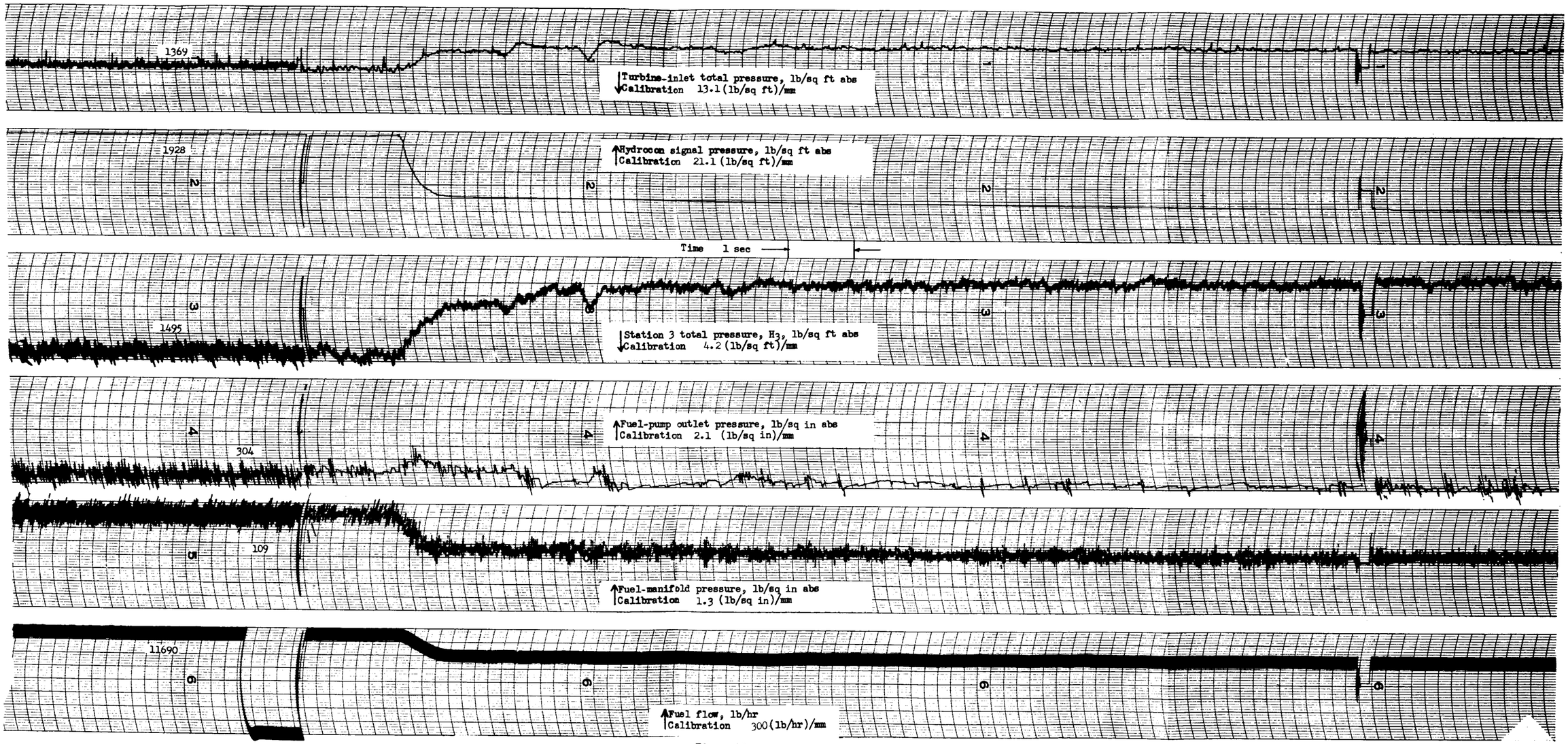

Figure 15
Oscillograph traces showing variations of different fuel control parameters during a step-change in hydrocon signal pressure. Altitude, 67000 ft ; flight Mach number 2.75; engine-inlet air temperature, 956° R; engine air flow, 80.3 lb/sec.

PRELIMINARY TRANSIENT PERFORMANCE DATA ON THE FUEL CONTROL OF THE XRJ47-W-5 RAM-JET ENGINE

3231

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maa - 1/29/54

Engines, Ram Jet 3.1.7

Engines, Control - Ram Jet 3.2.6

Welna, Henry J., and Smith Ivan D.

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Abstract

A brief program was undertaken to determine the characteristics of the fuel control (Hydrocon) of the 48-inch diameter XRJ47-W-5 ram-jet engine. The control was installed on the engine in a free-jet facility. Data were obtained in the form of oscillograph traces showing the time history of the fuel system pressures, fuel flow, and engine inlet total pressure in response to changes in the control signal pressure. The data presented in this report are for step changes (from ±15 to ±30 percent) in Hydrocon signal pressure at simulated altitudes of 67,000 and 73,000 feet at a flight Mach number of 2.75.